NERVOUS SYSTEM BLOCK

29th Lecture

Physiology of Basal Ganglia

PHYSIOLOGY TEAM – 430

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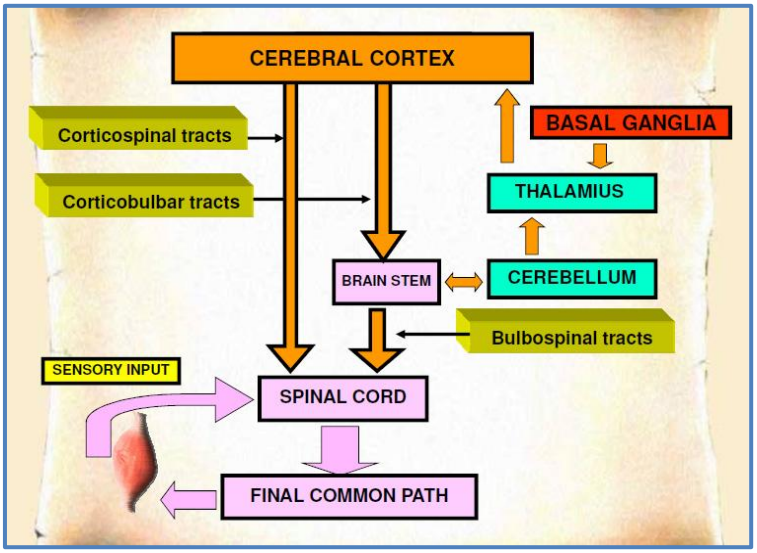
Physiology of Basal Ganglia

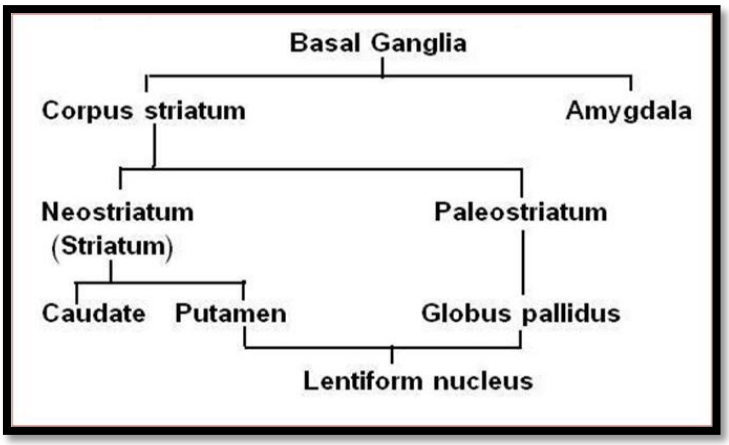
- **Revision of Pathways:**



Notes:

- Motor activity initiation mainly comes from Cerebral Cortex
- Basal Ganglia is connected to the Cerebral Cortex via the Thalamus
- Cerebellum + Basal Ganglia are mainly for correction of movement

- **Revision of the Anatomy of Basal Ganglia:**



Notes:

- **Anatomically, the Basal Ganglia contains:**
  Caudate, Putamen and Globus Pallidus Nuclei
- **Functionally, two nuclei are related to Basal Ganglia:**
  Substantia Nigra and Subthalamic Nucleus

- **Connections of Basal Ganglia:**

1- Main input:

Comes from Cerebral Cortex and enters via the Neostriatum (Otherwise known Striatum)

2- Main output:

Goes to the Cerebral Cortex via Thalamus (to motor area)

3- Connections in between

- **Basic Circuits of Basal Ganglia:**

1) Motor Loop (Putamen Circuit):

- Concerned with learned movement
- The movements we do without thinking "subconsciously"
- For example, playing with a pen or shaking the leg while concentrating in class, or kicking a football randomly

2) Cognitive Loop (Caudate Circuit):

- Concerned with cognitive control of sequences of motor pattern
- It means you translate sensory inputs with the memory storage in your brain into motor activity
- For example, if you see a lion in front of you (sensory input), you know that it is a dangerous animal (memory storage), so you will run away (motor activity)

3) Limbic Loop:

- Involved in giving motor expressions to emotions
- For example, if someone asks you how are you? Either you will say: "I'm fine thank you what about you ☺", or you will say: "I'm fine -_-", noticed the difference !?

4) Occulomotor Loop:

- Concerned with voluntary eye movement (Saccadic movement)

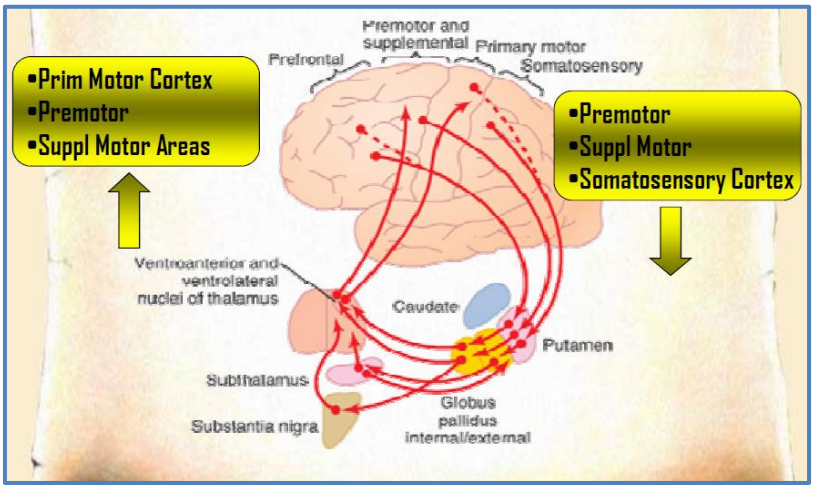
Notes:

✓ Putamen circuit is for already learned movement "subconsciously", but if you are doing it for the first time it will be done by the Caudate circuit, then it will be memorized in the Putamen

✓ Caudate circuit is for Cognition (Thinking), and the Putamen Circuit is for the execution of the motor activity

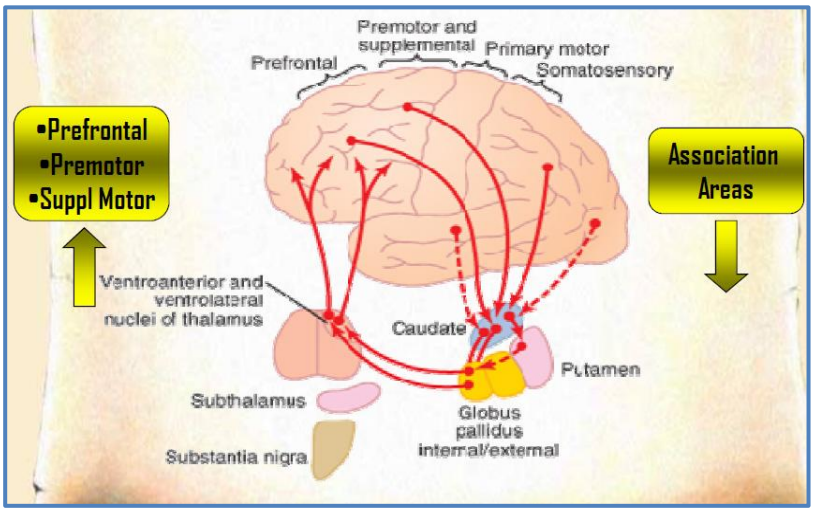
✓ If you ask someone to draw something randomly while he is talking to you he will use (Putamen), but if you ask him to draw a car for example he will focus (Cognition, Thinking) so he will use (Caudate), That's the difference

- **Putamen Circuit (Motor):**



- **Afferent:**
  - ✓ Premotor area
  - ✓ Supplementary area
  - ✓ Somatosensory Cortex
- **Efferent:**
  - ✓ Primary Motor Cortex
  - ✓ Premotor area
  - ✓ Supplementary area

- **Caudate Circuit (Cognitive):**



- **Afferent:**
  - ✓ All Association areas
- **Efferent:**
  - ✓ Prefrontal area
  - ✓ Premotor area
  - ✓ Supplementary area

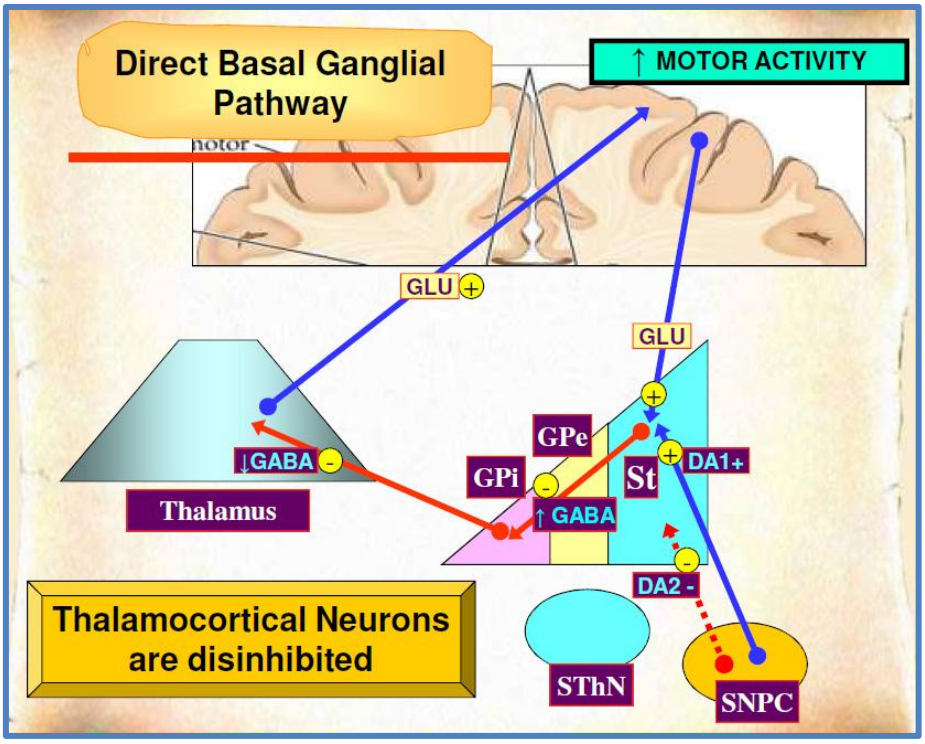
Notes:

✓ One of the Caudate Circuit is to determine Largeness and Rapidness of movements, for example, if you are writing notes with a doctor you will make your handwriting small and fast, but if you are explaining something to students on the board you will make your handwriting slow and large to help them understand

- **Basal Ganglia Pathways:**

- If you want to do motor activity, for example flexion of arm, you will use Agonist muscle (Biceps) + Antagonist muscle (Triceps)
- The Agonist muscle (Biceps) will be stimulated to do the flexion, mean while, the Antagonist muscle (Triceps) will be inhibited to make the flexion smooth
- Two pathways known as the direct and indirect pathways will produce the activity of both Agonist and Antagonist muscles

❖ **Direct Pathway (Agonist Muscle):**

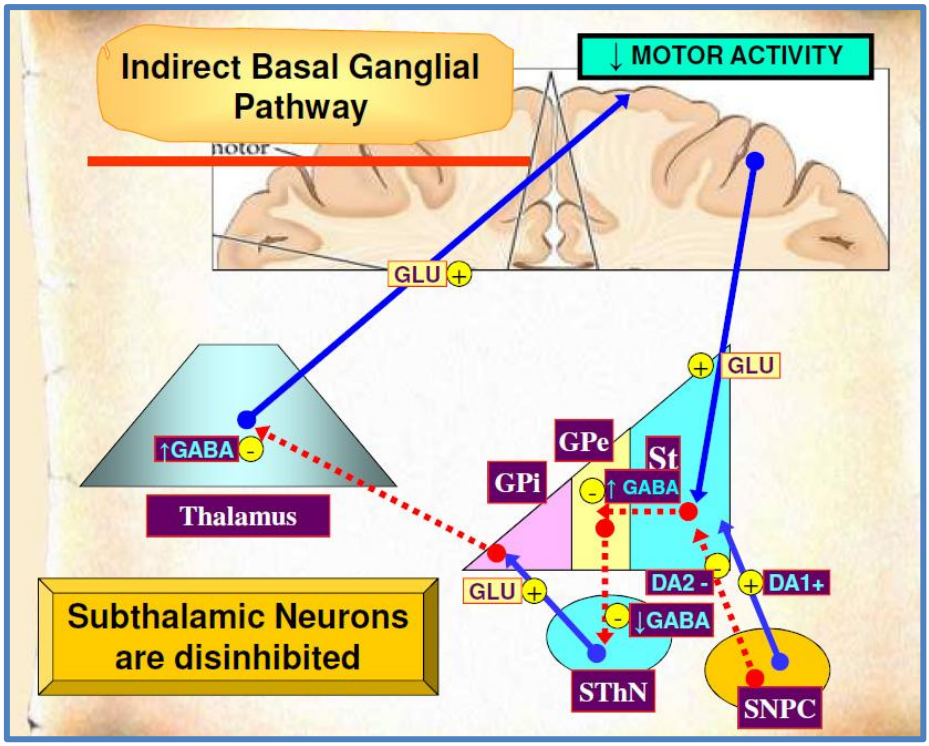


Cerebral Cortex will release Glutamate to Striatum → Striatum will be excited to release GABA → The GABA release will inhibit Globus Pallidus → When Globus Pallidus is inhibited → Less GABA release to the Thalamus → When less GABA to thalamus → Less inhibition of thalamus (Plays the role of excitation) → Increase Glutamate release from thalamus to the Cortex again → finally increased motor activity to the Agonist muscle

Very Important Note !!!!

✓ Main function of the **Direct pathway** is to increase muscle activity via **Disinhibition of the Thalamocortical Neurons**

❖ Indirect Pathway (Antagonist Muscle):



Cerebral Cortex will release Glutamte to Striatum → Striatum will release GABA to Globus Pallidus externus (Lateral) → GABA will inhibit Globus Pallidus externus → Less GABA will be released from Globus Pallidus externus to Subthalamic Nucleus → Less inhibition of Subthalamic Nucleus (Plays the role of excitation) → Subthalamic Nucleus then will release Glutamate to Globus Pallidus internus (Medial) → Stimulation of Globus Pallidus internus → More GABA will be released from Globus Pallidus internus to Thalamus → Inhibition of Thalamus → Less Glutamate will be released from Thalamus to the Cortex again → Finally decreased motor activity to the Antagonist muscle

Very Important Note !!!!

✓ Main function of the **Indirect pathway** is to decrease muscle activity via **Disinhibition of the Subthalamic Neurons**

General Notes of the pathways:

- **Glutamate is released from:**
  Cerebral Cortex, Thalamus and Subthalamic Nucleus
- **GABA is released from:**
  Striatum, Globus Pallidus externus and internus
- The conclusion of both direct and indirect pathways is to make the movement smooth

- **Metabolic Characteristics of Basal Ganglia:**

- High Oxygen consumption
- High Copper content in Wilson's disease (Copper intoxication):

✓ Autosomal Recessive
✓ Copper binding protein Ceruloplasmin is low
✓ Lenticular degeneration occurs

- **Functions of Basal Ganglia:**

- Control of movements
- Planning and programming of movements
- Cognition (Thinking)

- **Basal Ganglia Disorders:** We have two types of disorders:

- **Hyperkinetic:**

✓ It means that there's a damage in the Indirect pathway (Responsible for inhibition), and when it is damaged the Direct will take over and this will result in Hyper-activation of muscles
✓ Examples: Hemiballismus, Huntington's disease, and Athetosis

- **Hypokinetic:**

✓ It means that there's a damage in the Direct pathway (Responsible for excitation), and when it is damaged the Indirect will take over and this will result in Hypo-activation of muscles
✓ Examples: Parkinson's disease, and Drug induced Parkinsonism

Movement Disorder	Features	Lesion
Chorea (Other name for Huntington's disease)	Multiole quick, random movements, usually most prominent in the appendicular muscles	Atrophy of the striatum Huntington Chorea
Athetosis	Slow writhing movements, which are usually more severe in the appendicular muscles	Diffuse hypermyelination of corpus striatum and thalamus
Hemiballismus	Wild flinging movements of half of the body	Hemorrhagic destruction of contralateral subthalamic n. Hypertensive patients
Parkinsonism (Most Important)	Pill rolling tremor of the fingers at rest, lead pipe rigidity and akinesia	Degenration of Substantia Nigra